Gamma-ray Computed and Emission Tomography for Pool-Side Fuel Characterization

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ABSTRACT:

In the effort to advance the next generation of nuclear reactors which incorporate advanced safety features and economy, new nuclear fuels and accident tolerant fuels are being designed. To test the performance, reliability and behavior of these fuels under irradiation, experiments are conducted at nuclear test reactors to simulate fuel irradiation over years or in beyond-design conditions. Evaluating each fuel's performance requires a systematic investigation of the dimensional, structural, mechanical, thermodynamic, chemical, and neutronic characteristics under a range of conditions. Ideas are being sought to extend the suite of experimental characterization techniques which allow researchers to measure these physical properties in a rapid and non-destructive way and without needing to remove the fuel from the underwater cooling ponds or fuel canals that they reside after irradiation.

This project is tasked with building a compact, high-resolution underwater gamma ray computed tomography platform which utilizes a strong gamma ray source, a precision controlled sample manipulation system, and an array of radiation detectors to measure the transmission of gamma rays from the source through the fuel as well as gamma ray emissions from the decay of fission products in the fuel itself to produce three-dimensional maps of composite structural and chemical information.

This project will produce three major deliverables: (1) a carefully optimized design for the tomography platform (2) the platform itself, which will be custom built and tested and (3) installation of the system and training in its use at the Advanced Test Reactor (ATR) at Idaho National Laboratory.

This is a three-year phased project. The first year will consist of design and numerical simulation of the system's performance, producing simulated tomographic data that demonstrates the capabilities of the system. In the second year, individual components of the system will be built, tested and integrated into a whole. Testing with mock nuclear fuel will also be performed in year 2. In year three, the system will be shipped and installed pool-side at the ATR facility and tested. The progress and results of this work will also be shared within the scientific and engineering communities through peer-reviewed journal articles and at conferences.

This tomography system will provide a broadly useful database of combined structural and chemical information about nuclear test fuel to both experimenters and fuel modelers alike. Structure and fission product chemistry/transport are among the most important parameters to consider when evaluating a potential fuel's performance. An additional yet broad impact of the system will in its ability to demonstrate how a high resolution gamma ray tomography system may be constructed and used in other areas of technology where tomographic characterization of dense materials is sought.